Pure Silicon Dioxide from Sand

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Experiments Acid, Dioxide,Sand, Silicate, Silicic, Silicon, Sodium

Introduction

Quartz is the second most common mineral in the surface of our planet. It also happens to be a crystalline form of Silicon Dioxide. The most common component of sand happens to be quartz. In this experiment we're going to take sand, something everyone can get their hands on, and turn it into pure Silicon Dioxide that can be used in future chemical experiments.

Reagents

- Sand;
- Sodium Hydroxide;
- A strong acid;
- Tap Water;

Dangers

This experiment is going to involve high heating and molten Sodium Hydroxide. Molten Sodium Hydroxide is extremely corrosive and very dangerous. When handling it, wear thermal gloves and goggles (in other situations not portrayed here, a Face Shield is necessary when handling molten Sodium Hydroxide). Indications of safety measures will be detailed along with each step of the procedure.

- Sodium Hydroxide is corrosive. Large quantities of it are going to be handled. Goggles and gloves are recommended.
- Depending on the acid of choice, goggles and gloves may be necessary.

Procedure

First, the sand to be used should be washed (actually, this step is optional as explained in the Theory section). Weight about 300g of sand into a beaker.

Fill the rest of the Beaker with water.

Stir well and decant. Repeat this process at least twice. Once you're done, set aside to dry.

You need to wait until the sand is dry.

For the next step, you're going to need a crucible of some sort. It has to be large and, remember, it will get messy. Use something you don't mind ruining. I just use an old pan I have for this king of thing. It can be dirty or rusty as any solid contaminants will be removed later on.

Here is a picture of the pan I use:

Aluminium pans or crucibles **cannot** be used because they react with Sodium Hydroxide.

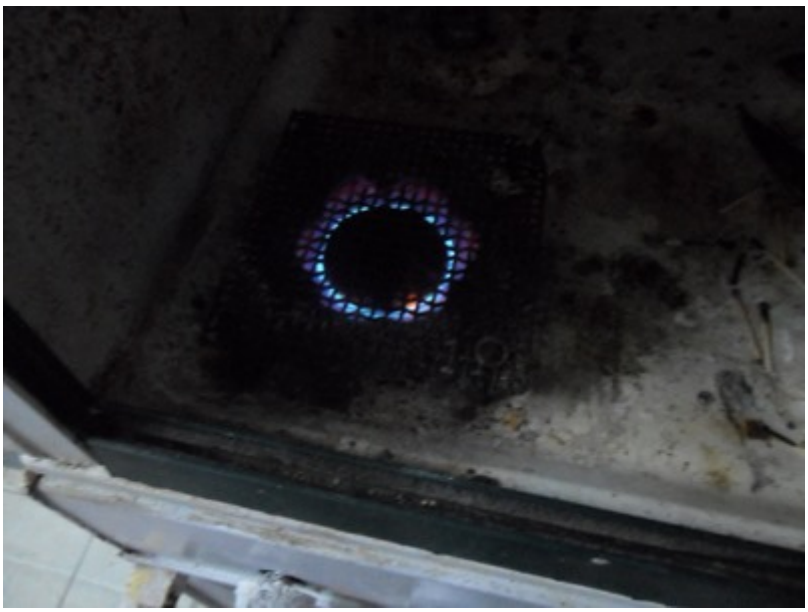
To your crucible of choice add the dried sand (yes I lost 15 grams drying it, not exactly sure how 😛).

Then, add 155g of Sodium Hydroxide.

You're going to be using 155g of Sodium Hydroxide. Gloves and goggles should be worn.

Use a spoon (or any other object) to mix everything. It is important to mix the reagents well.

Now comes the heating part. The mixture must be heated to, at least, 320ºC. This temperature must be maintained for, at least, 10 minutes. To accomplish this, I just used an old stove. Actually, the place you're going to see is my test area for dangerous stuff. Pardon me for the ugliness of said stove:



You can see the flame I used to heat the mixture. It is nothing extraordinary and any stove can reach the temperature mentioned. Some hotplates may even go that high in temperature. If you don't have a thermometer to test if you have a hot enough heat source, you can use Lead. Lead has a melting point of 327.46ºC. If you can melt Lead inside your crucible, then you're good to go.

Here is the mixture 1 minute after heating begun:

Here is the mixture 10 minutes after heating begun:

Here is the mixture 50 minutes after heating begun:

As you can see, there is a sharp difference in color. After your mixture turns grayish/white let it heat for 10 more minutes. Then, take it of heating.

Once the mixture cools down, transfer it into a beaker.

Note: The heating made very fine, dry particles that contain Sodium Hydroxide leftovers. If you're not careful while transferring the powder to the beaker, these particles will become airborne and you will probably breath them in (which is immediately noticeable because of the cough and pain it produces).

Fill the beaker with water and stir well.

Note: After adding the water, the grayish/white powder seems to disappear and sand reappears. This is explained later, in the Theory section.

Now set up for gravity filtration. You can use vacuum filtration if you want, but I find it unnecessary.

Decant the solution into the paper filter to filter it.

Here is the filtered solution:

> Note: You probably already noticed that I am not using laboratory glassware to hold the solution (just a regular jar). The next step is going to involve making Silicic Acid which tends to stick to everything. Furthermore, it readily decomposes into Silicon Dioxide. When it sticks, it is almost impossible to remove it without scratching the glass. Thus, I recommend using glassware that you don't care about ruining.

So, now you have to acidify the solution to produce Silicic Acid. I recommend using a strong acid to ensure full conversion to Silicic Acid. This is going to be further explained in the Theory section. I decided to use **100mL** of 98% Sulfuric Acid.

Because the reaction between the solution and Sulfuric Acid is very vigorous, I needed to resort to an Addition Funnel.

This is a picture after a small addition of Sulfuric Acid:

Here are two pictures of the jar after all the Sulfuric Acid was added:

This reaction forms some strange stuff (Silicic Acid), resembling jelly. This compound must now be purified before converting it into our final product (Silicon Dioxide).

There are various ways to purify it. The process I use is fast and easy to carry out, but has the disadvantage of losing some product.

Before starting the process, get another crucible (this time you must use a clean one). It can be anything that can sustain about 100ºC and you don't mind getting all stained by Silicon Dioxide (do not use laboratory glass that you care about). I just used an Aluminium pot.

After taking care of the crucible, get a beaker (you may return to your laboratory glassware now) and fill half of it with water.

Now, get a spoon and fill the spoon with the jelly:

Submerse the spoon into the beaker and swirl. The jelly quickly sinks to the bottom of the beaker.

Repeat the process once more. I only add two spoons to every 500mL of Water. After you've added the two spoons, decant the water. You will see that only the biggest chunks of jelly are going to stay at the bottom of the beaker. I just discard the ones that decant off with the water (and that's how some product is lost in this method). Fill with water to wash the jelly and decant again.

Now get this washed product into your crucible.

Once your product is safely inside the crucible, repeat the whole process again. Get two spoons of jelly, add to 500mL of water, decant, add another 500mL of water, decant and add the washed jelly to the crucible. Do this until, obviously, there isn't any more jelly to wash.

When you're finished, start heating the crucible. I just needed to heat mine for about half an hour. Once all the jelly has turned into powder you're done.

And now you have pure Silicon Dioxide. For extra purity, take the Silicon Dioxide powder formed and wash it with water a few times. However, if the jelly was well washed, this is unnecessary.

> Note: On the end of an experiment I like to weight my final product. This time, after I made the Silicon Dioxide I immediately used it for another experiment and forgot to weight my final product. Anyway, I weighted the part that I had saved for later.

The final weight was 135,9g of Silicon Dioxide (100g that I already used + 35,9 shown in the pictures).

Theory

This experiment has a lot of details to cover so I will do my best to try to cover them all.

First, why wash the sand? It isn't really necessary. However, I collected my sand from a place usually frequented by cats and dogs. I didn't want the sand to smell bad in the heating process so I washed it to remove any urine or excrements.

As stated, Sand is composed of Quartz, among other things. The percentage of Quartz in sand differs greatly. On average, quartz makes up about 70% of sand.

Quartz is a crystalline form of Silicon Dioxide. However, sand is not good to use in chemical experiments. First, because it is only 70% quartz (has a lot if impurities). Second, because Quartz crystals often enclose impurities inside them (that's why many are colored).

Molar Masses

Sodium Hydroxide: 39,997 g/mol

Silicon Dioxide: 60,08 g/mol

Sodium Silicate: 122,07 g/mol

In this experiment, I used Sodium Hydroxide to react with Quartz to form Sodium Silicate, as follows:

$2NaOH(l) + SiO_2(s) \rightarrow Na_2SiO_3(s) + H_2O(g)$

As you can see, 80 grams of Sodium Hydroxide react with 60 grams of Silicon Dioxide. I used 285g of sand. However, sand is only about 70% sand. So, only about 200g of that sand was Silicon Dioxide. So, 267g of Sodium Hydroxide react with 200g of Silicon Dioxide. However, I only used 155g of Sodium Hydroxide (about 60% of the theoretical quantity). I did so because I didn't want to waste any Sodium Hydroxide. Sand is free and you can get kilograms of it easily. Sodium Hydroxide isn't as freely available as sand. My sand could be 60% Silicon Dioxide. Or 50% for that matter. Using only 155g ensures that almost all Sodium Hydroxide gets used and none gets wasted.

When molten, Sodium Hydroxide reacts with Quartz (Silicon Dioxide) to form Sodium Silicate and Water (vapor). Sodium Hydroxide melts at, about, 318ºC. That's why, in the procedure, I heated up the mixture to this temperature. Once it melts, Sodium Hydroxide "coats" the sand particles, making the mixture turn into a grayish/white color. The Sodium Silicate formed is also white and forms in the outer part of each individual grain of sand. Thus, the whole thing turns whitish.

As far as I know, the only component in sand that reacts with Sodium Hydroxide is Silicon Dioxide. However, there are probably a few more side reactions happening.

Sodium Silicate is soluble in water. When the reaction is done, water is added to the mixture to dissolve the Sodium Silicate. Any leftover Sodium Hydroxide dissolves as well. That's why sand "magically" reappears in this step.

The next step was to acidify the solution. Sodium Silicate reacts with acids to form a very complex compound known as Silicic Acid.

As 155g of Sodium Hydroxide was used, the theoretical amount of Sodium Silicate in solution (considering all NaOH reacted) is about 236g. The acidification of Sodium Silicate is very complex and stoichiometrically obtaining quantities of acid to use is almost impossible. Empirically, I've found that about two moles of Hydronium ions are needed.

So, which acid to use? I had about 800mL of solution before acid addition. 100mL of 98% Sulfuric Acid provided me with about 2 moles of Hydronium ions (the ions responsible to make Silicic Acid). To obtain this quantity of Hydronium ions I would have needed, for instance, 350mL of 33% Hydrochloric Acid. This would have made a too large volume of solution/jelly to work with. However, if no Sulfuric Acid is available, you can just use Hydrochloric Acid.

Finally, all that is left to do is to transform the Silicic Acid into Silicon Dioxide. Silicic Acid readily decomposes into amorphous Silicon Dioxide when mildly heated.

So, to summarize:

Quart(sand) –> Sodium Silicate –> Silicic Acid –> Silicon Dioxide

Final Notes

I enjoy this type of experiment because they show that one can turn simple everyday "chemicals" like sand into useful reagents for the Amateur Lab. Hope you enjoyed the reading and please comment and leave some feedback.